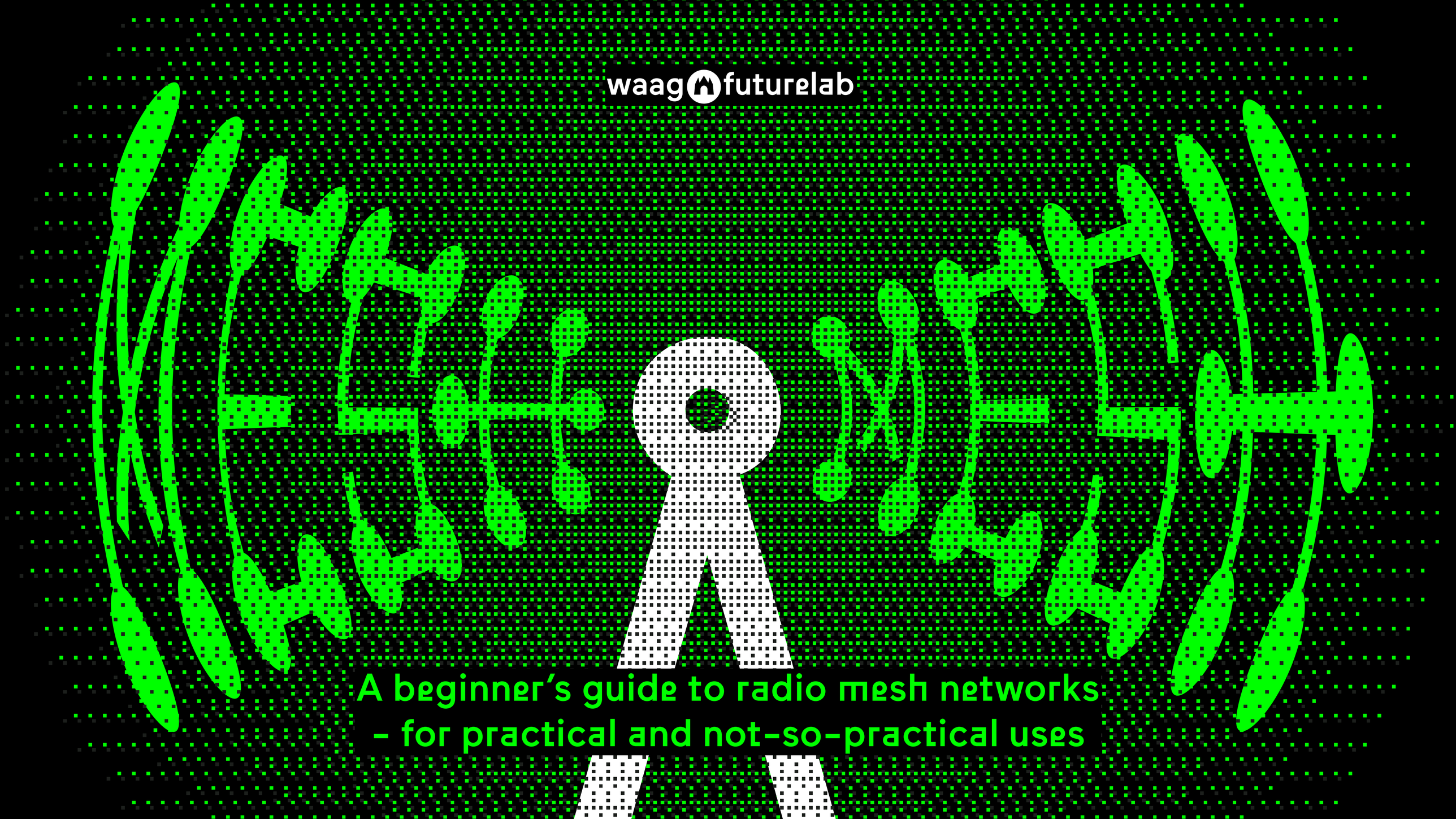
waag futurelab

Wireless Reality

A beginner's guide to radio mesh networks
– for practical and not-so-practical uses



Are you interested in mesh networks, but don’t know where to start?

The world of mesh networks is diverse and it can feel overwhelming to start exploring the possibilities that it offers.

This guide is going to ease you into the idea of radio-enabled mesh networks – explaining what they are, highlighting why they are relevant now, how we use them to improve our technological resilience, and what some of the more creative and artistic uses are. We won’t be diving into deep technical details or recommending the best devices to use. Rather, this guide will take you through the basics of the components of such networks.

1:What is a mesh network?

A mesh network is a system of multiple interconnected devices (or nodes) that can be used for communication. The devices talk directly to each other, and pass messages along without needing a central internet connection.

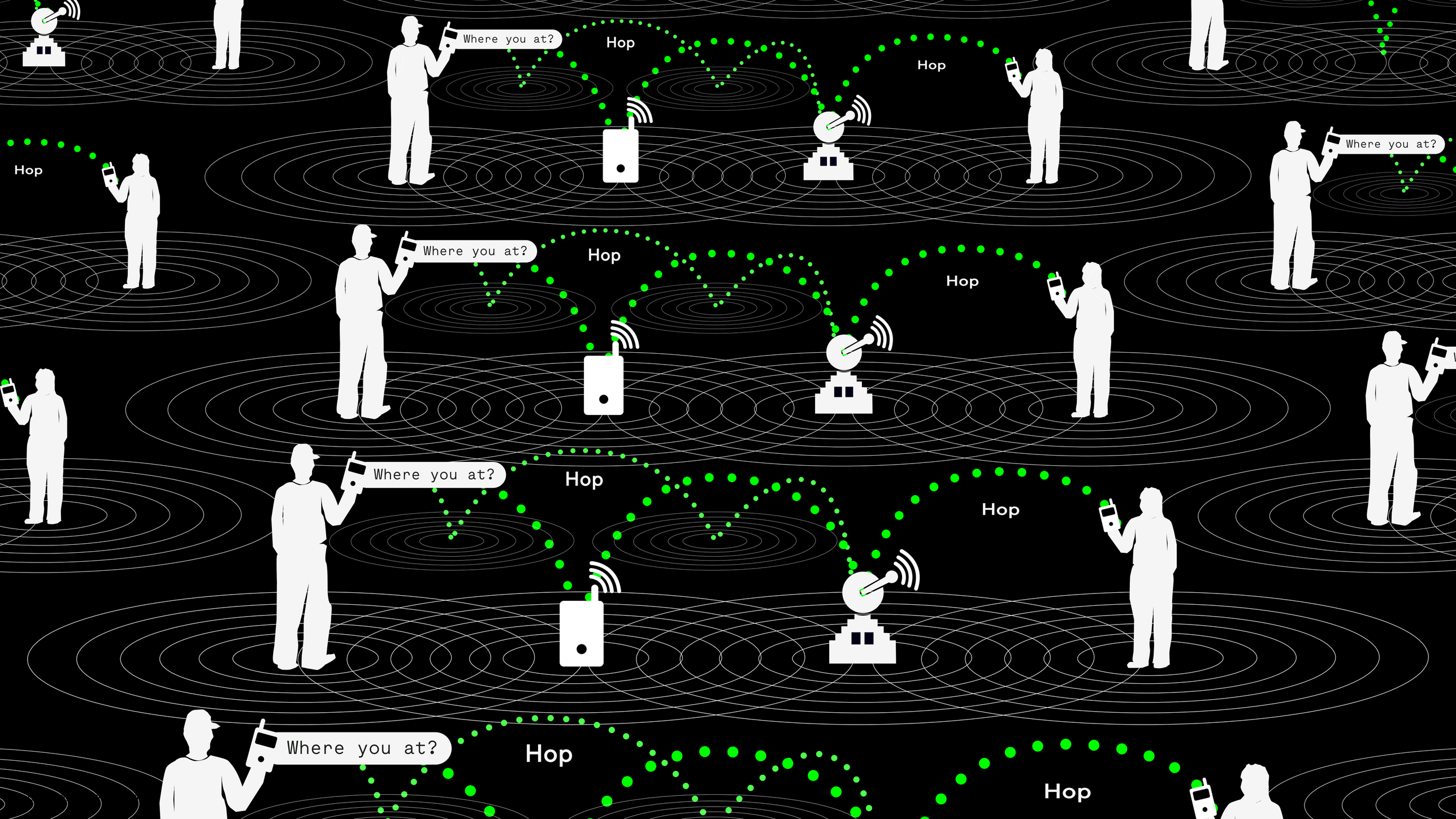
Instead of going through a central point that distributes a message, devices can send information using the available network of devices. The message can then reach its final destination by "hopping" through available net of nodes.

Think of moving houses with the help of friends. Instead of one person carrying a box the entire way by themselves, you can create a chain of people to pass the box along.

In this way, transporting the box requires less effort, and it arrives closed at its final destination for unpacking.

Mesh networks work like that: passing a message directly from one to another. You can create a wireless mesh network or connect devices directly with each other using cables.
A basic principle is that you avoid a centralised distributor.

In this guide, we will focus particularly on wireless radio mesh networks with a focus on LoRa (Long Range) set-up.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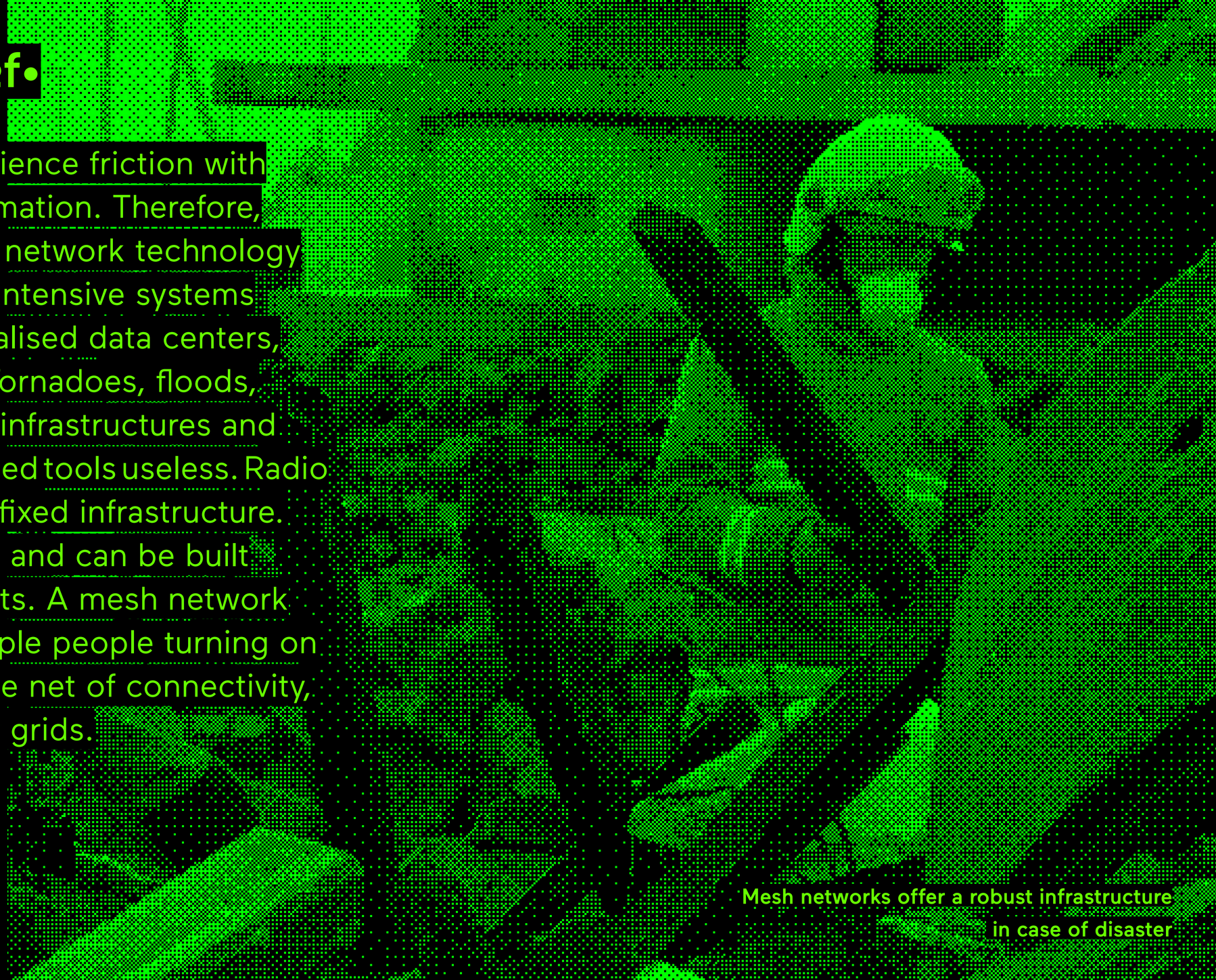
2:How are mesh networks used?

Mesh networks are great in situations where physical network infrastructure is either damaged, unavailable, or unsafe to use. Mesh networks don’t try to replace traditional internet infrastructure. Instead, they offer a "good enough" layer of communication, that can be used as a back-up – or as a non-big tech alternative. It is slower, sometimes glitchy, but more resilient and independent. People use it in many ways. Here are some examples:

•Natural disaster relief•

In our daily lives, we rarely experience friction with connectivity and access to information. Therefore, we often forget that most of our network technology is sustained by fragile, resource-intensive systems such as submarine cables, centralised data centers, and continuous energy supply. Tornadoes, floods, or earthquakes can impact such infrastructures and effectively render our internet-based tools useless. Radio mesh networks do not rely on a fixed infrastructure. A radio device is small, portable, and can be built and repaired with simple elements. A mesh network can emerge organically: by multiple people turning on their devices, creating an invisible net of connectivity, independent of wires and power grids.



Mesh networks offer a robust infrastructure in case of disaster

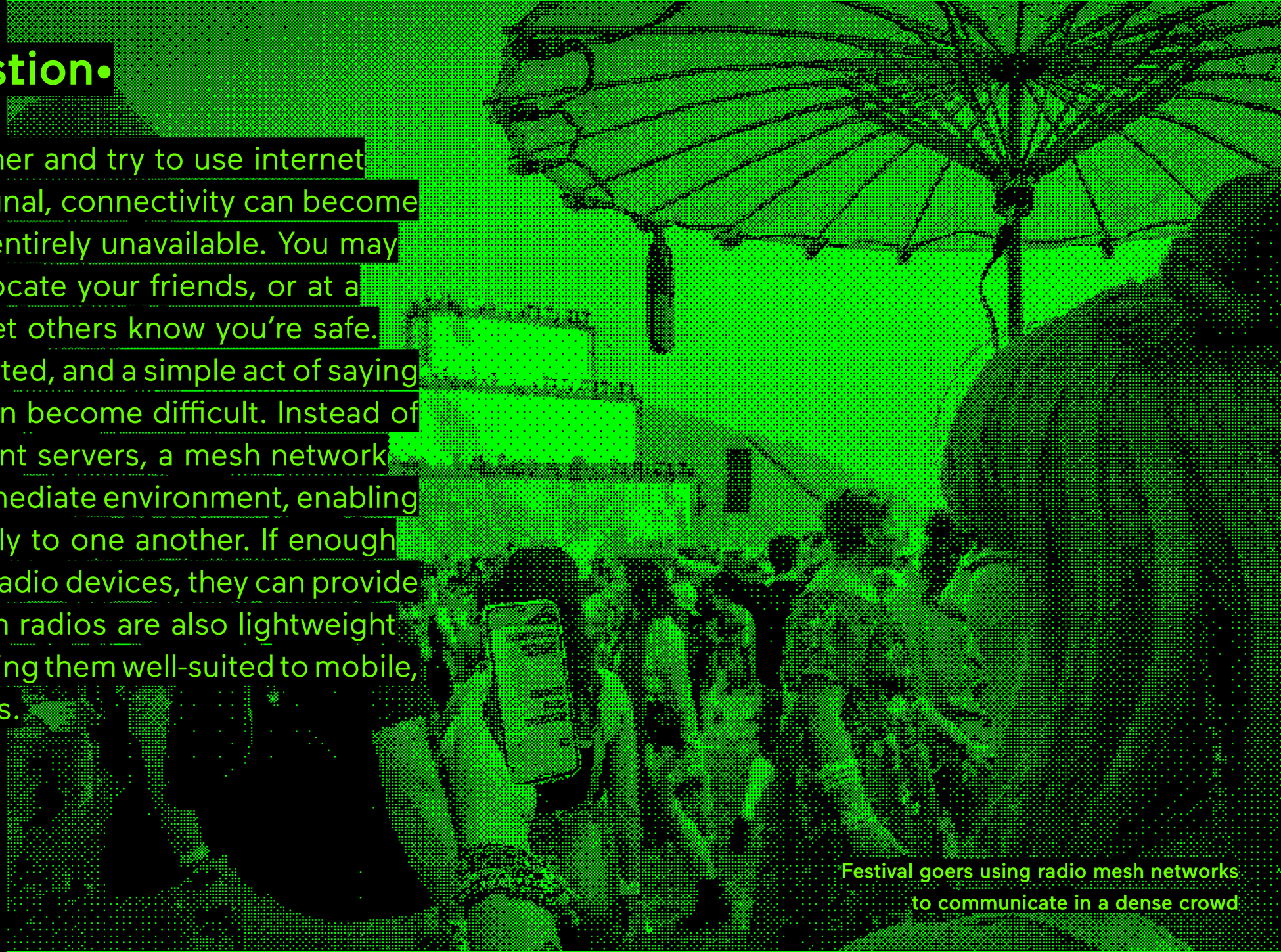
•Network blackouts•

In 2025, citizens of Spain, Portugal, and a small area in south-east France experienced a total electrical blackout. The power was eventually restored, but in some locations it took 20 hours after its start to do so. With climate change intensifying and electricity demand growing, particularly with the expansion of energy-intensive AI systems and digital infrastructures, we are likely to see such events happen more often. In such conditions, radio nodes can become an alternative. They require little power to charge, can therefore remain connected and send messages even during an overall blackout. Though they do not aim to replicate the scale of the internet, they allow for a "good enough" communication base as back-up.

During the 2025 blackout in Spain, people gathered on the street around a battery powered radio

•Network congestion•

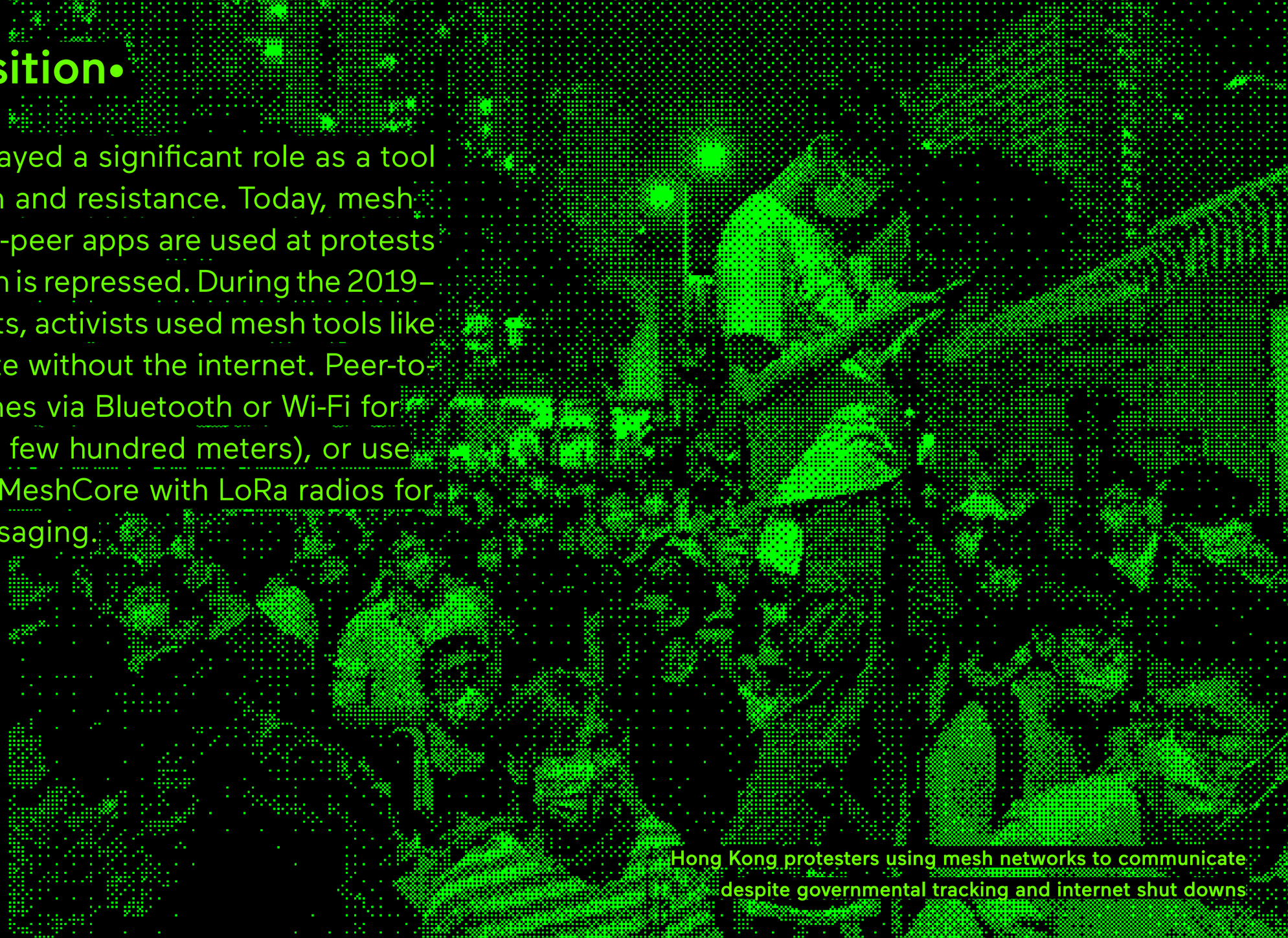
When a lot of people gather and try to use internet apps like WhatsApp or Signal, connectivity can become unreliable, expensive, or entirely unavailable. You may be at a festival trying to locate your friends, or at a demonstration trying to let others know you're safe. Networks become congested, and a simple act of saying "I'm here" or "I'm safe" can become difficult. Instead of reaching outward to distant servers, a mesh network can operate within the immediate environment, enabling devices to connect directly to one another. If enough people in the crowd have radio devices, they can provide a stable connection. Mesh radios are also lightweight and relatively rugged, making them well-suited to mobile, high-density environments.



Festival goers using radio mesh networks to communicate in a dense crowd

•Political opposition•

Historically, radio has played a significant role as a tool for political organisation and resistance. Today, mesh radio and offline peer-to-peer apps are used at protests and places where speech is repressed. During the 2019–2020 Hong Kong protests, activists used mesh tools like Bridgefy to communicate without the internet. Peer-to-peer apps can link phones via Bluetooth or Wi-Fi for short-range networks (a few hundred meters), or use tools like Meshtastic or MeshCore with LoRa radios for much longer-range messaging.



Hong Kong protesters using mesh networks to communicate despite governmental tracking and internet shut downs

3:What do I need to start?

To join or create a wireless radio mesh network you don’t need much. But the set up varies depending on the firmware you choose.

Basic set-up:

1. Radio Node
2. Repeater / Relay Node
3. Client Device
4. Power System
5. Firmware

1. Radio Node

This is the most important device.
A radio node can send and receive radio messages and may forward them to other nodes.

Nodes come in many forms:
- Ready-made devices with screens and buttons
- Small DIY set-ups (like a microcontroller + antenna)
- Minimal boards connected to a phone or computer

2. Repeater / Relay Node

A repeater is simply a node placed in a strategic location to extend the network. These extend the range and connect distant nodes.

- Positioned higher up (window, roof, hill)
- Helps messages travel further
- Connects distant parts of the network

If you live in a large urban area, chances are there are already some repeaters in the city. You can check that by searching online for the mesh map in your city. You can also help strengthen the network by installing one yourself!

3. Client Device (how humans interact)

This is the interface device people use to send or read messages.

- Often a phone or computer
- Connects to a radio node (via Bluetooth, USB, etc.)
- Provides a simple interface (like a chat app)

For example, both Meshtastic and MeshCore allow you to use your phone as a client.

4. Power System

Every mesh device needs a power source. Most, however, are very low-powered and chargeable via USB cable or even solar panels.

5. Firmware

Depending on your preferences, technical skills, location, and local mesh community, you might opt for different firmware. Technology around mesh networks is changing fast, as of writing this guide most beginners interested in LoRa opt for Meshtastic or Meshcore.

Both of these firmwares have advantages and disadvantages. Here is a short overview ▶▶

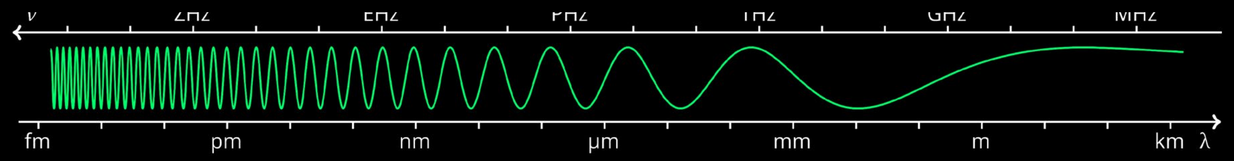
•Meshtastic•

- **Getting started:** Easy to start, requires minimal set-up
- **Devices:** Works with a phone app (Bluetooth) + ready-made LoRa devices → very beginner-friendly
- **How it works:** Message routing is mostly automatic and pre-configured → less to think about
- **Community:** Established community. It has been around for longer. Lots of tutorials, documentation, and active users → easier to get help
- **Range:** Great at festivals and more remote areas.

•MeshCore•

- **Getting started:** More manual configuration and more set up options
- **Devices:** Works with a phone app (Bluetooth), but it is optional – you can use it without!
- **How it works:** Routing of the messages (how messages travel) is more customizable → more control, but more complexity
- **Community:** Growing community and recently gaining in popularity because of more reliable connections and better message routing (how successful messages are in arriving at their destination)
- **Range:** Can be more reliable over longer distances if repeaters are set up

4:So what is radio anyway, and how can I use it to send and receive messages?



•Basics•

The air around us is filled with electromagnetic waves, often called radio waves. These waves occur naturally, but we have learned how to generate and control them to carry information.

Governments and institutions don’t create radio waves; they produce rules on how to use these radio waves, so we don’t interfere with each other when using them.

•Spectrum•

Radio waves operate within spectrums, which are divided into bands based on frequency. The spectrum itself isn’t something that gets used up like a physical resource. However, if too many devices try to transmit on the same frequency at the same time, signals can interfere, making communication unreliable. As we increase the amount of information we need to send with every message, we face increasing congestion and interference in commonly used frequency band.

For that reason, most of the spectrum is regulated and reserved for specific uses, such as police, fire, aviation, marine, AM/FM radio, and TV.

But some parts are open and license-free and this is where many mesh networks operate.

•LoRa•

Many radio mesh networks live in sub-GHz frequency bands that favor distance over speed.

Radio mesh set-ups (for example when using MeshCore or Meshtastic) can achieve long signal ranges using LoRa technology. LoRa is designed to send small amounts of data over long distances while using very little power. This makes it especially well-suited for mesh networks, where range, energy efficiency, and resilience matter more than speed.

Both long-range and short-range radio technologies - such as Wi-Fi, Bluetooth, and NFC - use standardised communication protocols to send and receive information. These protocols define how devices communicate, ensuring that signals can be understood and coordinated across the network.

•Protocol•

All radio technologies, whether long-range (LoRa) or short-range (Wi-Fi, Bluetooth, NFC), use protocols.
A protocol is simply a set of rules that tells things how to communicate with each other. The protocol keeps everything organised so the network doesn’t flood itself with noise. In a radio mesh network, a protocol ensures that multiple devices can work together, passing messages across the network without creating noise or confusion.

5:Getting creative with radio

The world of radio technologies is diverse and this short guide cannot cover them all. Instead, we want to inspire and show that there are many ways in which you can engage with them. In this guide we talk about creating mesh networks with the use of radio technology, but there are also steps before that with which you can start. To give stage to some of these explorations, we interviewed artists, asking about their views on interacting with radio technologies and their motivations behind interacting with mesh networks.

Christy Westhovens

"An invisible layer... on top of the city, one that reshapes how people relate to their surroundings."

Christy, in collaboration with other hackers, runs workshops on reticulum – another communication network also capable of creating radio mesh networks. For Christy, engaging with radio is like interacting with an invisible map overlaying the city, an additional layer that only becomes perceptible when you tune into it. When moving through urban space with radios in hand, the act of networking becomes spatial and social: walking, testing, mapping, and encountering others.

This technology is not perfect; stretch, break, reconnect. Buildings interfere. But through this active experimentation, the distance and urban environment become something you can feel. In this way, mesh is less an infrastructure to install than knowledge and skill to share.

What appears is a different city: not experienced through roads or platforms, but by proximity, cooperation, and the ephemeral reach of signals. A city you don't just inhabit, but continuously rediscover.

christywesthovens.com

Reticulum workshop, photo by tommi.space

Frederick & Philippe Ekwaro-Osire

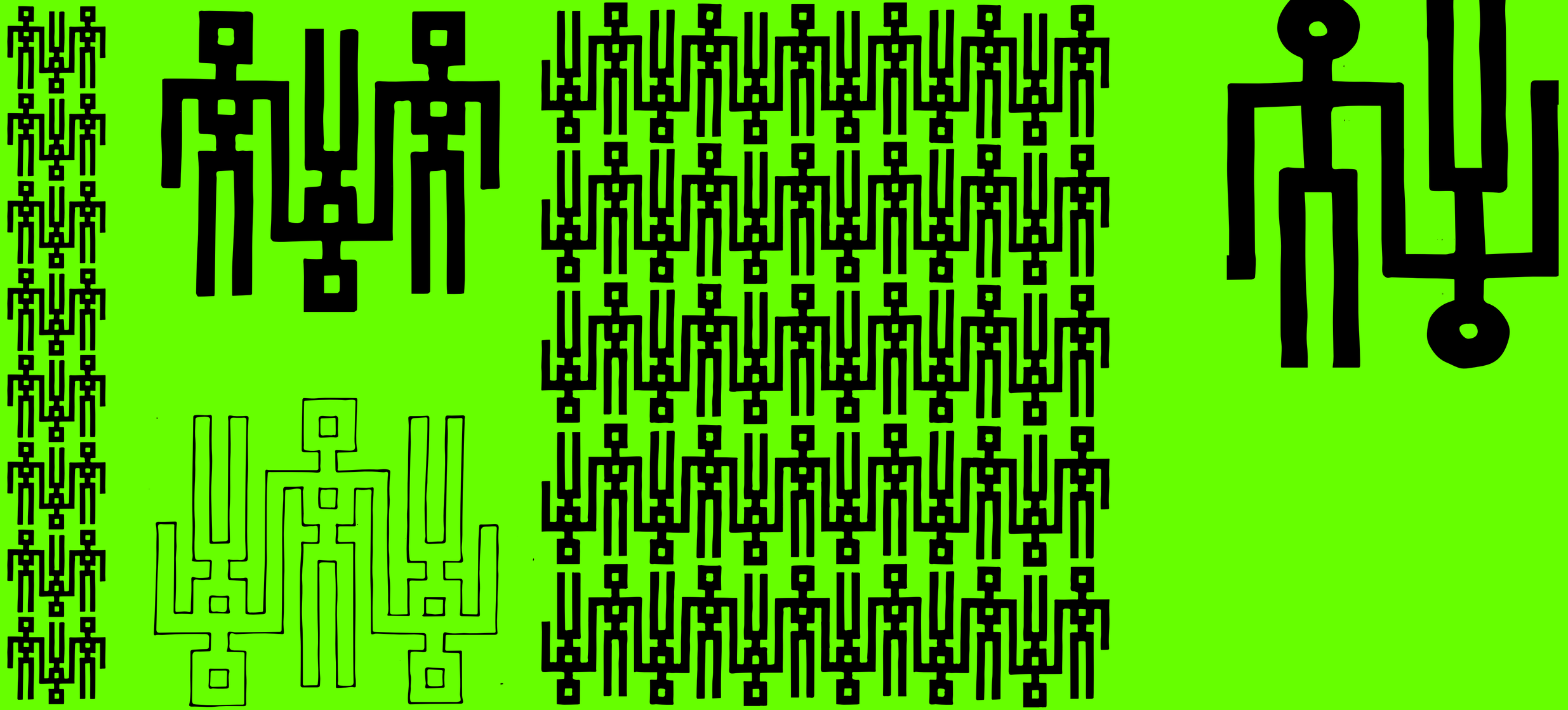
“Let the grass take root and spread and spread”

Frederick and Philippe are part of the People of the Earth collective. Frederick and Philippe were inspired by mesh networks, thinking of them as something akin to how human connections naturally grow, something almost resembling a spread of grass. Just like grass mesh networks grow without a central point of control. This technology takes root where conditions allow, extends through connection, and survives through community effort.

With their project Rooted Networks, they hope to expand and deepen community relations by becoming a node, connecting the community of Black digital creatives in the Netherlands with eco-conscious communities working in the digital sphere. Their approach resists the extractive logic of centralised systems, instead emphasizing care, distribution, and shared stewardship "to make each other more resilient."

In their approach, a mesh network is not just a tool for communication; it is a way of building infrastructures that endure because they are actively cared for and maintained.

peopleofearth.nl



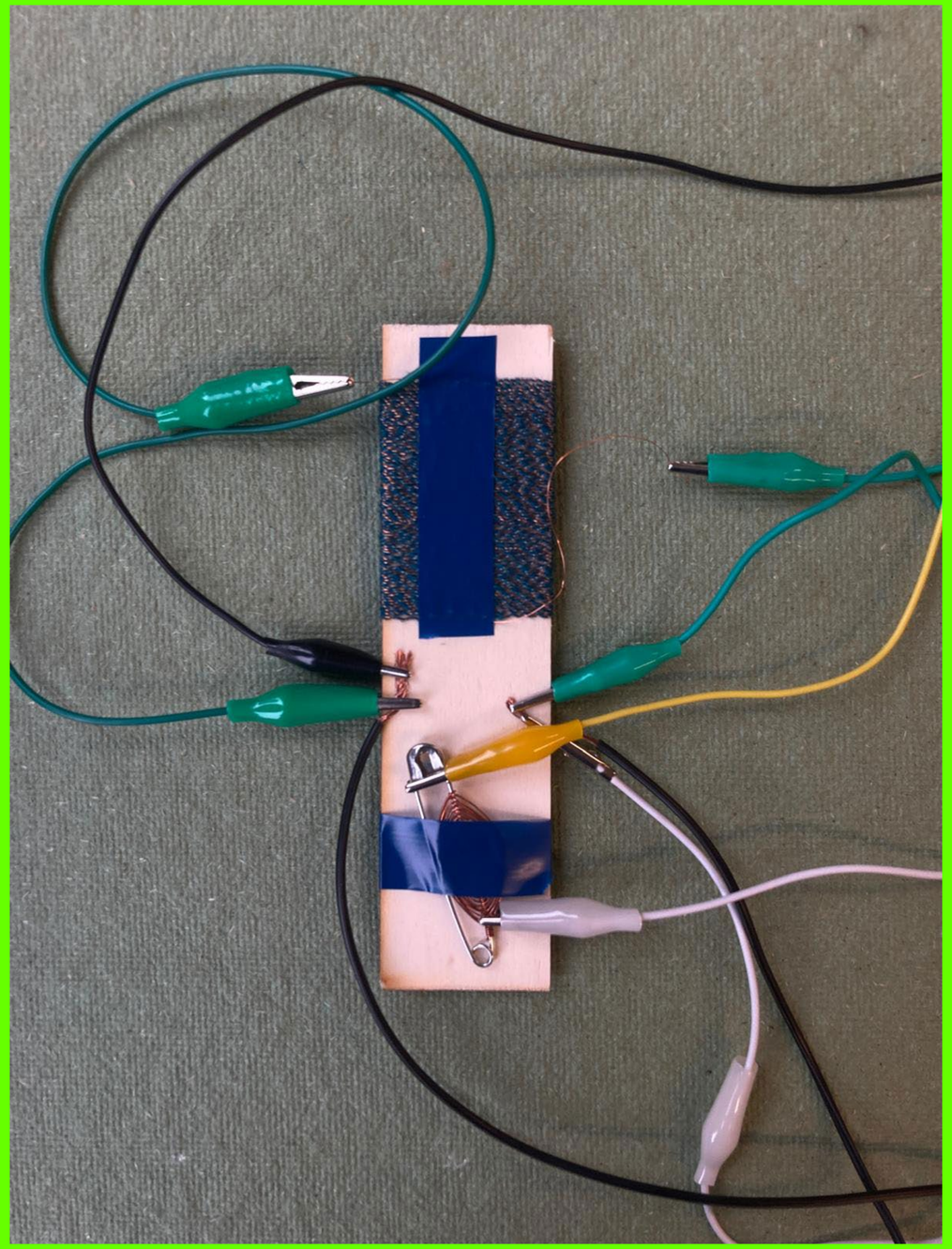
People of The Earth logotype

Martina Farrugia

"..when you make, build something so simple technically (crystal radio), there's this really beautiful connection with making with your hand, but also embodying this practice by physically taking your creation outside and interacting with the environment"

A radio can be as simple as a coil, a diode, a piece of wire, a body leaning in to listen. Martina returns to one of the simplest forms of radio: the crystal radio. In contrast to contemporary mesh devices, which run through firmware and allow for advanced back-and-forth communication, this basic set-up does not require batteries or external power; it gathers signals moving through the air and (if you get lucky) it translates them into sound. Martina uses this exploration as a way of grounding radio as technology in something graspable. Building your own radio receiver with the use of a crystal requires a different kind of attention, slower, more patient, more attuned to the environment. Radio becomes less about control and more about tuning in and recognizing that communication is already happening. For her, learning how to create it herself was about rediscovering the practice that has been present around us all along.

@martinafarrugia



Martina's experiments

6. Experiments

Waag Futurelab researches what mesh networks look like when they move from theory into practice. By collaborating with citizens, Waag sets up test networks. With these networks we look at the technical and social aspects of setting up and running decentralised radio-based communication systems.

Working with cities across the Netherlands, Waag's projects test both the technical performance and the social dynamics of mesh communication systems. As mentioned earlier, mesh networks are often framed as tools for emergencies, useful during blackouts or infrastructure failure. But an equally important question is how they might become meaningful in daily life.

Currently we are working on ▶▶

•Community pilot Amsterdam•

With the municipality of Amsterdam we work on the pilot project NodeNet, where 30 citizens were given node devices, technical training and support. This pilot helps us understand both technical limitations of such networks in the dense urban environment of Amsterdam city center (looking at interference and range possibilities), but also how people relate to the devices (are they easy to use, what are the incentives that can build a habit around them).

•Antennas and repeaters•

By placing additional nodes in strategic locations - such as rooftops or elevated points - we explore how far the network can stretch, and how stable it can become. These small interventions help us understand how a mesh network can gradually grow stronger through shared effort.

•Co-creation with municipalities•

Co-creation workshops are an important step of exploration for governing bodies. During these workshops we ideate what mesh networks can do beyond being applicable in crisis preparedness. So far, some of the ideas born out of these workshops included: helping schools and parents with smartphone-free communication with children, establishing radio building skills through mesh network programmes run in repair cafés and aiding public service workers with better communication.

About Waag Futurelab

Technology is not neutral. As Futurelab, Waag researches and design technology for a better future. Waag reinforces critical reflection on technology, develops technological and social design skills, and encourages social innovation. Within these practices, Waag focuses on regenerative technology: systems that do not merely take, but also restore and give back. Through practice-led research and participatory design, Waag combines science, art and community initiatives to create technology that strengthens ecosystems and communities.

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Do you have any questions or would you like to discuss this publication further?
Please email Ola Bonati (Waag Futurelab) at ola@waag.org

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